

Lazzaro Spallanzani's *Opuscoli* of 1776

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INTRODUCTION

Lazzaro Spallanzani's (1729-1799; Fig. 1) disputations with John Turberville Needham (1713-1781) and Georges Louis Leclerc, Comte de Buffon (1707-1788), reached their apogee in 1776 with the publication, at Modena, of *Physical Observations on Animals and Plants* (*Opuscoli de Fisica, Animale e Vegetabile*) (Fig. 2). The book is subtitled *Observations and Experiments on Infusion Animalcula Occasioned by an Examination of Some Articles from a New Work by Mr. Needham* (*Osservazioni e Sperienze intorno agli Animalucci delle Infusioni in occasioni che si esaminano alcuni Articoli della nuova Opera del Sig. de Needham*). Included in this span of 304 pages (identified as "Tomo Primo") are two letters, one quite long, one brief, written to Spallanzani in January and April of 1771, by Charles Bonnet (1720-1793), a well-known preformationist, "relative to ideas on infusion animalcula" (*relative al Suggetto degli Animali infusori*).

Opuscoli was not Spallanzani's first work dealing with the extremely controversial and confused (at the time) issue of generation mechanisms. In 1765 his *Microscopical Observations in Regard to the Generation Theory of Needham and Buffon* (*Saggio di Osservazioni Microscopiche Concernenti il Sistema della Generazioni dei Signori di Needham e Buffon*) appeared, followed 4 years later by Abbé Regeley's translation of the work, *New Investigations, Microscopical Discoveries, and the Generation of Organized Bodies* (*Nouvelles Recherches sur les Découvertes Microscopiques, et la Génération des Corps Organisés*) (Fig. 3). This translation was furnished with copious "notes" supplied by Needham, and the original work occupies only 138 pages, while the notes, which are, in fact, a detailed rebuttal of Spallanzani's experiments, occupy 159 pages.

THEORIES OF BUFFON AND NEEDHAM

To obtain a clear idea of the nature and importance of *Opuscoli*, it is necessary to sketch

briefly the background and scientific positions occupied by Buffon (as he was generally known) and Needham with respect to their views on generation. This matter has been excellently recounted by Gasking (2). The former had developed his ideas on the subject for some years before they appeared in 1749 in the section of his monumental *Histoire Naturelle* titled *Des Animaux* (volume II). While visiting in England in 1738, Buffon met and discussed his theory with Abbé Needham, and this encounter established the basis for their later collaborations. As for Needham, his views were expressed at great length in December 1748, in a paper titled "A Summary of Some Late Observations Upon the Generation, Composition, and Decomposition of Animal and Vegetable Substances; Communicated in a Letter to Martin Folkes Esq., President of the Royal Society, by Mr. Turbervill [sic] Needham, Fellow of the same Society" (Philos. Trans. 45:615-666).

Buffon obviously was influenced in the construction of his theory by P. Gassendi's (1592-1655) *De Vita et Moribus Epicuri* (1647), a revival of Epicurus' theory leading to development of the later micromechanical outlook in biology, particularly in the realm of all vital phenomena, not only sexual reproduction. Buffon's ideas on nutrition and generation are not always easy to translate into meaningful terms of modern biology, but he proposed, in essence, that every living being was built from a large number of organized bodies consisting of organic molecules, microscopically or sub-microscopically small. In a plant or vegetable, the whole body served as a template or mold (*moule*) into which absorbed food was fitted. In an animal or man, the entire mold was an assemblage of smaller molds, one for each part of the body. Ingested food was postulated to contain both living and brute matter (*matière vive et brute*), and the body separated the two, rejecting the latter by the excretory mechanisms of kidneys and alimentary tract. All of the molds, each in its own part of the body, took from living matter of food, now in the blood,

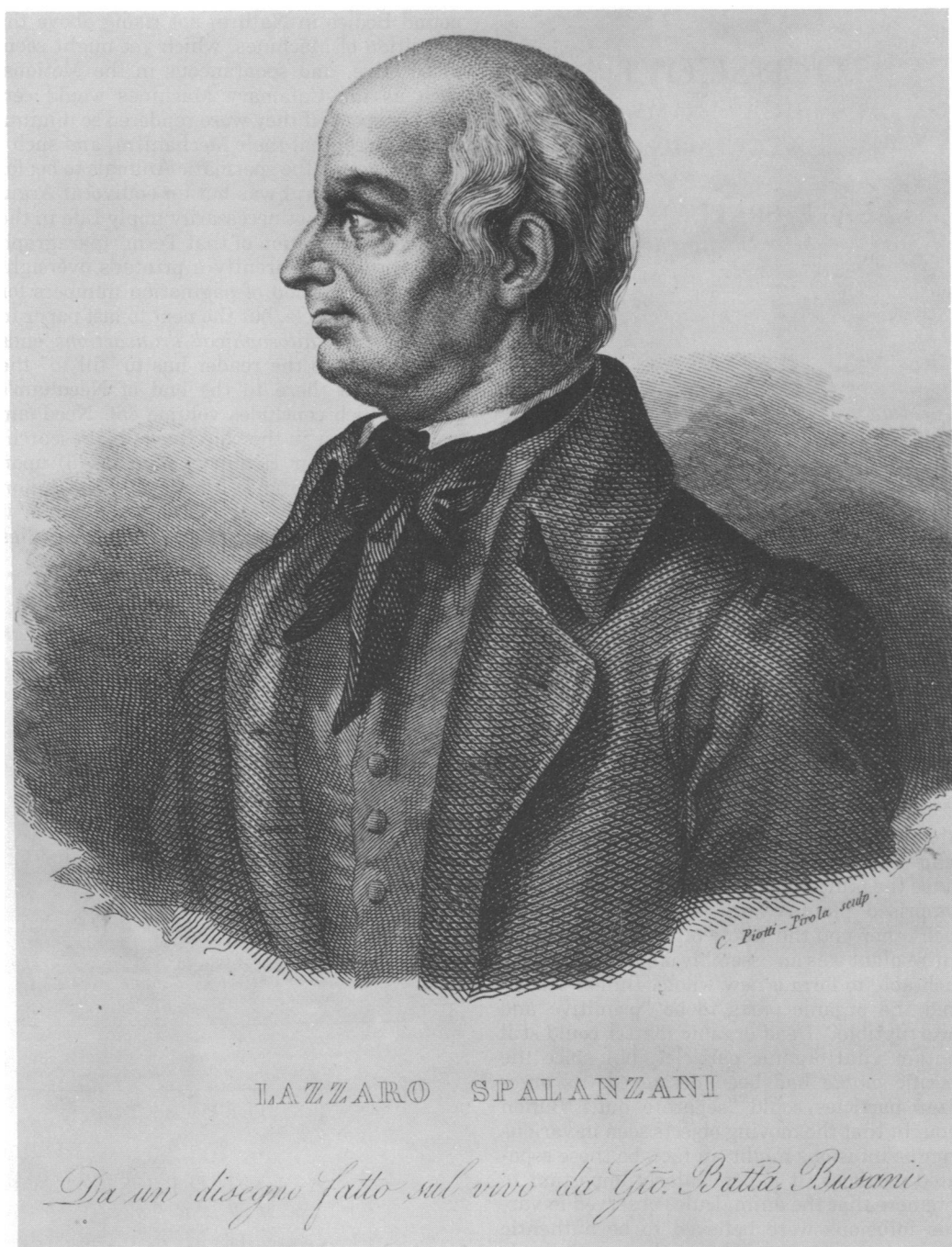


FIG. 1. Lazzaro Spallanzani by Giovanni Battista Busani (courtesy of the National Library of Medicine).

those organic molecules best suited to them, and hence they expanded, or grew, in all directions. When an organism was fully grown, its molds no longer required all of the organic molecules available to them, and the excess went,

via the blood, to those parts of the body involved with reproduction. Buffon believed that for reproduction, the excess food formed a tiny organized body whose mold was similar to, or a copy of, the mold of the entire body. On the

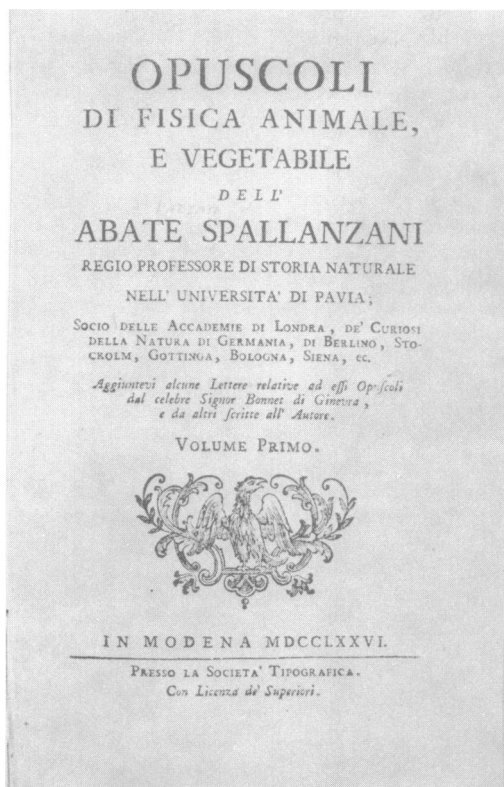


FIG. 2. Title page of the 1776 edition of Spallanzani's *Opuscoli*.

other hand, reproduction in simple plants was achieved from the smallest possible part, because the multimolecular organized bodies that comprised plants were considered both like each other and the whole organism. Thus, the entire plant was an assembly of *identical* bodies each able to form a new whole. Buffon considered the organic parts to be "primitive and incorruptible." Dead organic matter could still contain vital organic particles, but since the specific *moule* had been destroyed, its organized particles could "separate out." Buffon thought that the moving objects seen in various organic infusions might, in fact, be these separated particles. It is particularly important to note here that the animalcules observed in various infusions were believed to be authentic living organisms carried into them aurally. It would be Needham's main task to determine whether this was true. It was at this critical point, then, that Spallanzani's main experimental endeavors would be directed.

At first Needham wrote: "For my part, I was then, as I had been before, so far of his [Buffon's] Opinion, as to think there were Com-

pound Bodies in Nature, not rising above the Condition of Machines, which yet might seem to be alive, and spontaneous in the Motions, such as the Calamary Machines would certainly appear, if they were rendered so diminutive as to conceal their Mechanism, and such I then suspected the spermatric Animals to be: for Motion in general was but an equivocal Argument, and did not necessarily imply Life in the common Acceptation of that Term" (paragraph 19, page 634; apparently a printer's oversight led to the omission of pagination numbers for Needham's article, but the next to last paper in this issue of *Philosophical Transactions* ends at page 614, so the reader has to "fill in" the blanks from there to the end of Needham's paper, which concludes volume 45). Needham was quite clear in the objective of his research, namely: "... our Enquiry commence(d) upon Seed-Infusions, from a Desire Mr. de Buffon had to find out the organical Parts, and I, if possible, to discover which among these Bodies

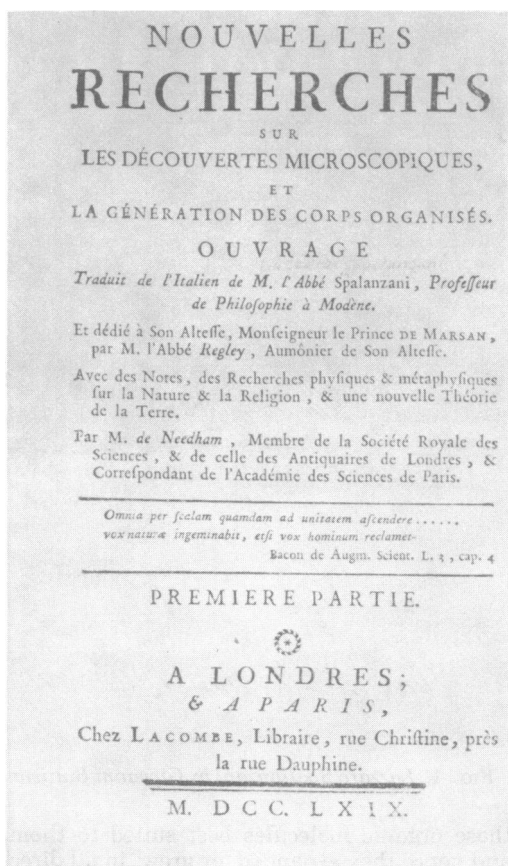


FIG. 3. Title page of Needham's French translation of Spallanzani's *Saggio*.

were strictly to be look'd upon as Animals, and which to be accounted mere Machines" (paragraph 19, page 634.).

Needham was primarily an experimentalist, and his talents far exceeded Buffon's in this regard, but as his inductions from hazardous observational work lead him on he finally concludes: "It was not till some time after this, that, determin'd to convince myself and others, without any Possibility of Doubt, whether these moving Atoms were really produced from without, or from the very Substance infus'd: I discovered all the common microscopical Animalcules, the spermatic ones not excepted, were to be rang'd in the same Class, and that their Generation was very different from that of all other animated Beings" (paragraph 20, page 637.) This conclusion, quite at variance with Buffon's hopes, was derived from results initially based on the microscopical examination of roast meat gravy "... hot from the Fire, and shut ... up in a Phial, clos'd with a Cork so well masticated, that my Precautions amounted to as much as I had sealed my Phial hermetically," and also "... upon three or four Scores of different Infusions of animal and vegetable Substances ... all which constantly gave me the same Phaenomenon with little Variation, and were uniform in their general Result" (paragraph 31, pages 637, 639.) Thus it was that Needham found it necessary to shift his position radically and he wrote, "... we began to lay down a Distinction between animated and mere organiz'd Bodies; which tho' far from being at this time groundless, yet afterwards proved false. These, and the spermatic Animals, we supposed to be of the latter kind; and to be produced in their respective Fluids, by a Coalition of Active principles ... whilst we thought on the contrary, that the ordinary microscopic Animalcules, with strong Characteristics of spontaneous Motion and Animation, were to be class'd among Animals, and imagin'd them to proceed from Parent individuals of their own Species" (paragraph 20, pages 636-637).

Needham now had abandoned his preconceived distinction between the animalcules of infusions and the so-called atomical ones, and adopted the view that "... vegetative Powers ... reside in all Substances animal or vegetable, and in every part of these Substances, as far as the smallest microscopical point" (paragraph 25, page 644.) One does not find Needham suggesting that organic molecules form patterns that are replicas of the whole organism, and he emphasized his discovery of the existence of a "vegetative Force." He observes

"... hence it is probable that every animal or vegetable substance advances as fast as it can in its Resolution to return by a slow Descent to one common Principle, the Source of all, a kind of universal Semen; whence its Atoms may return again, and ascend to a new Life" (paragraph 29, page 654.) Buffon was still explaining the origin of spermatic animals by "... an evolution and combination of organical parts." Thus, in Needham's view, some animalcula of infusions derive only from "seeds" producing beings like themselves, and these are present in the air and, therefore, in newly prepared unheated infusions, whereas those seen in vessels containing heated, sealed infusions, are resultants of the action of a vegetative force acting on the organical molecules constituting the infusion. In either case, all infusoria were considered to belong to the same class. It apparently never occurred to Needham to test the validity and soundness of his experimental conditions since he was quite blinded by the enormity of his great "discovery."

SPALLANZANI'S POSITION: PREFORMATIONISM

Spallanzani was a preformationist and furthermore, an "ovist." He firmly believed that *all* parts of a *new* individual were preformed within the ovum. Since it was difficult to explain how differentiated parts could arise from unorganized materials, 17th century preformationists had assumed that *all* living things were organized by God at the moment of creation. The first female of each species had present within herself all future generations of her kind. Each generation gave rise to the next until all of the initially created ova had reached their maturity—then the species became extinct. This view was known as *emboîtement*, and it was preformation plus *emboîtement* that was the essence of the theory in the 18th century.

Spallanzani, along with A. Haller (1708-1777) and C. Bonnet, were the three great preformationists of this century. During the years 1730-1760, preformation theory became less readily accepted, although the ovist version gave it new life for a considerable time, largely due to the efforts of these three men. Incidentally, none of them began as a preformationist, but became convinced of the correctness of this theory later in their careers.

The work contra Needham and Buffon represented only a small facet of Spallanzani's investigations on generation, but it is the part relevant to microbiology. In passing, it may be noted that for all of Spallanzani's experimental

flair, and despite the fact that his results generally have remained firm, the work did little to clarify the basic biological issues of the time, and indeed, his results were misinterpreted by the need for forcibly fitting them into current preformationist dogma.

EXPERIMENTS WITH INFUSIONS

As a preformationist, Spallanzani could not persuade himself to the view that the animalcula of infusions were brought to life by a concatenation of vegetative force with organic molecules. C. Bonnet already had written of a "pre-existence of infusoria." Thus Spallanzani set about to determine other reasons for their presence in Needham's infusions. The prior experiments of his countryman, F. Redi (1621-1697), and the Frenchman, L. Joblot (1645-1723), clearly provided models for Spallanzani. In Redi's case, insects were shown not to arise spontaneously from decaying meat by the simple expedient of covering vessels containing it with a thin cloth, thus excluding their egg-laying parents (*Esperienze Intorno alla Generazione degl'Insetti*, 1668). And Joblot's experiments, even more to the point, that hay infusions boiled for 15 min and then covered with parchment did not give rise to any "living insects" or infusoria (*Descriptions et Usages de plusieurs Nouveaux Microscopes*, 1718). It was because of Spallanzani's expertise as an innovative experimenter that the results documented in the *Opuscoli* turned out the way they did. As Spallanzani wrote in the concluding chapter (12) of part II (page 203): "The infusion animalcula are simply not 'vital beings' in Needham's sense, but exhibit true and characteristic properties of animality" (*Gli Animali infusori non sono Esseri semplicemente vitali conforme il pensare del Needham, ma hanno le vere, e caratteristiche note dell'Animalita*). Movement was considered to be solely an "animal property" long after Spallanzani's time.

Most, but not all, experiments described in the *Opuscoli* consist of microscope observations made on infusions of kidney beans, vetches, buckwheat, barley, maize, mallows, beets, etc., heated in closed vessels for various periods of time, set aside to await developments that would be observed macro- or microscopically. The presence and viability of the animalcula was judged mainly on their ability to move or exhibit translational motility. Animalcular reproduction was noted macroscopically by an increase in turbidity of the infusion under study. The effects of vacuum, "electrical fluid," heat, cold, and various scents and liquids on the processes of motility and reproduction in animal-

cula constituted a major part of Spallanzani's investigations. As far as microscope technique was concerned, a statement in the *Saggio* of 1765 tells the reader that "... in my observations on infusion animalcula, I generally used an instrument similar to those of Leeuwenhoek's; it consisted of a single lens strong enough to easily observe them with precision, including the most delicate and fine details" [author's translation]. Spallanzani also used a compound microscope, but this notwithstanding, it is difficult, if not impossible, to identify today many of the organisms (mainly protozoa) he described in his work. The simple microscope was used in both a horizontal and vertical position, and candle light reflected from a concave mirror served as the illumination source. Spallanzani wrote that Needham used essentially the same microscope technique.

Nineteen flasks containing vegetable infusions were hermetically sealed and kept for 1 h in boiling water. Upon examination, after a period of incubation at room temperature, not a single animalculum could be detected. Nonetheless, if these infusions (of white kidney beans, vetches, buckwheat, barley, maize, and seeds of mallows and beets) were now freely exposed to the air, all showed the presence of infusoria in a day or two. Spallanzani concluded that long heating per se had no effect on the negative power of these infusions. Indeed, 11 kinds of seeds were reduced to ash by holding over burning coal, and infusions prepared from these ashed seeds also showed the presence of animalcula in a few days.

One learns from the *Opuscoli* that all animalcula die at a temperature "around boiling," but that "... all animalcula are not alike affected by cold." It is also noted that "... every fluid is not equally favourable for the expansion of animalcular eggs. Pure water alone is unfit for it; hence it is no longer a mystery, why in it, and much more in distilled water, we hardly ever see animalcula" (1).

In another section, Spallanzani observed that "... vapors of camphor ... occasioned sudden agitation and discomposure in the animalcula: they endeavoured to retreat from the malignant fumes, by retiring deep into the infusions" (1). Here, one might easily imagine, is an observation on negative chemotaxis—perhaps the first ever recorded. Spallanzani also determined that salt water, vinegar, ink, brandy, and spirit of wine were fatal to animalcula. One need not cite further examples of these simple observational experiments to ask, as Bonnet did, in his letter of 17 January 1771, referring to some of Spallanzani's experimental results, 4

years before their publication in the *Opuscoli*: "How can we refuse to assent to the general conclusions which you deduce from such decisive experiments? How can we refuse to agree, that the *vegetative* or *productive* power of our friend the Epigenicist is a perfect chimera?" (1).

Most microbiologists appreciate the importance of Spallanzani's work on infusion animalcula. His conclusions were sharply outlined, as we may gather from his statement: "As I could not then conceal my propensity to believe, that infusion animalcula originated from germs, neither do I hesitate to say, propensity has become perfect conviction. If the animalcula do not originate from the vegetative power, I do not see how we can ascribe their origin to any thing but eggs, seeds, or preorganized corpuscles, which we understand and distinguish by the name of germs" (1).

But, of course, the matter did not end with the appearance of *Opuscoli*, and as is well known, the Needham-Spallanzani controversy slowly faded away in a mist of equivocation. It has been pointed out on more than one occasion that spontaneous generation cannot be "disproved." One can only show that it does not occur under the experimental conditions advocated by proponents, or that erroneous conclusions were drawn from correct observations. Spallanzani's *bête noire* was his inability to devise an experiment that did not involve heating (or "torturing" as his adversary said) the air over infusions. This innovation came later in the work of F. Schulze (1815-1873) and H. G. F. Schröder (1810-1885) and T. von Dusch (1824-1890) (4, 5). Hence, an unequivocal conclusion, based upon incontrovertible experimental evi-

dence, that the air did not contain some heat-labile element essential for operation of a "vegetative power" was not possible in Spallanzani's time. The *Opuscoli* clearly foreshadowed the pattern of experiments in this direction, and in this respect Spallanzani's influence on future developments was more than passing, culminating in Pasteur's epic work nearly a century later (3).

Let us conclude, then, as the ASM observes and honors the 200th anniversary of the publication of *Opuscoli* and the great Italian master, with words from Dalyell, who stated in his translator's preface; "The acknowledged fame of the celebrated author of these tracts, and the importance of his numerous discoveries, are too well established to require any additional confirmation here."

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